474

VOLUME 80 SEPARATE No. 474

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

AUGUST, 1954

DUMPING AND LAND FILL

Report of a Subcommittee of the Committee on Refuse Collection and Disposal of the Sanitary Engineering Division

{Discussion open until December 1, 1954}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

THIS PAPER

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

DUMPING AND LAND FILL

Report of a Subcommittee of the
Committee on Refuse Collection and Disposal of
the Sanitary Engineering Division

This report on Dumping and Land Fill is one of a series produced by Subcommittees of the Sanitary Engineering Division's Committee on Refuse Collection and Disposal. Other subcommittees have reported on Collection; Reduction; Hog Feeding; Incineration; Composting and Grinding; and State Activities and Fiscal Aspects. These reports are being published as separates as they become available. While not consecutively issued or numbered, the reports will form a series representing the final report of the Committee on Refuse Collection and Disposal.

The committee consisted of:

Henry W. Taylor, Chairman

Norman W. Nester	Charles L. Senn
Newell L. Nussbaumer	V. M. Ehlers
Sol Pincus	Charles L. McGauhey

Members of the Subcommittee concerned are listed at the end of this and the other Subcommittee reports.

FOREWORD

In 1901, M. N. Baker made the following and now classic statement: "In no branch of municipal service has so little progress been made in the United States as in the disposal of garbage. Why do such conditions exist? First, because the sanitary collection and disposal is appreciated neither by the general public nor the city officials; second, because it is seldom recognized that the problems incident to final disposal are largely engineering in character and therefore should be entrusted to engineers."

Mr. Baker's statement could be enlarged in scope by substituting "refuse" for "garbage" and adding emphasis to the need for engineering technique and administration in collection as well as in disposal methods.

Activities of this Committee on Refuse Collection and Disposal since its inception may be briefly summarized as follows:

In 1935 the Sanitary Engineering Division appointed a "Committee on Technical Aspects of Refuse Disposal" and this Committee functioned until January, 1942, during which period four reports were submitted and abstracted in Civil Engineering. The final report of this Committee stated that:

> "due to the unusual activity of members of the Committee and on account of the lack of general interest in the subject under consideration at this time, together with a feeling on the part of the Committee Members that the subject is not particularly well adapted to Committee action, it is recommended that this Committee be discontinued."

The "unusual activity" of Members of the Committee still exists. Any lack of general interest in this subject has been replaced by the pressing necessity of solving a municipal problem which places increasing demands on public officials and engineers. A new Committee was appointed in 1947 and a progress report was submitted by the Chairman, Rolph Eliassen. This progress report outlined many of the facets of this subject and the need for application of engineering technique and administration.

At the 1949 meeting of this Society, a report was submitted by the Committee on "Advancement of Sanitary Engineering," which recommended the collaboration of the personnel from other technical organizations in the activities of Committees working on projects of broad scope. The recommendation met with quick approval and the present Committee has attempted to put these recommendations into tangible form by introducing Subcommittees who operate as task groups under the leadership of the personnel of the base Committee.

A report by the Committee in January 1950 confined itself to the organization of the Committee and Subcommittees with a prospectus of

objectives. A Progress Report was submitted in October 1952 and included the efforts of seven Subcommittees.

This report for 1953 may be considered as the final report of the Committee with the objectives originally stated by this Committee. The increased activity in research, in design and operation are leading to an extensive program of literature emanating from individuals, colleges, institutions and commissions and any attempt by this Committee to include all this data would be futile and a subsequent report would be largely a bibliography of this literature. In other words, present activities have extended beyond the scope of the Committee and involve a volume of current literature from various sources which are available from their original source.

This report is actually individual reports of the seven task groups acting as Subcommittees. The Chairman has considered that each group contains acknowledged experts within the scope allotted to it and has not, in general, modified or condensed the reports as submitted by these separate Subcommittees. He has also considered that it would be impracticable for the base committee as a whole to attempt to pass on or modify the work of the individual groups since the scope of these groups includes such a varied field.

The Chairman has reduced the personnel of various Subcommittees, as stated in this report, to those who have been able to devote time and submit data to their various Subcommittee Chairman. The Chairman wishes to express his appreciation of the cooperation of the Committee Members and Subcommittee members.

HENRY W. TAYLOR, Chairman

ASCE Committee on
Refuse Collection and Disposal

DUMPING AND LAND FILL

INTRODUCTION

The most primitive method of disposing of refuse is to throw it on the surface of the ground. Only one step beyond this is the practice of throwing it on the ground in some single location, originally, but not necessarily forever, beyond the confines of the community. The next refinement is to cover the refuse heap with inert materials such as ashes, broken masonry and waste earth, or earth materials quarried for that specific purpose. Finally, the most advanced method of refuse disposal on land areas involves a planned operation in which compacted refuse is incorporated in a fill in a manner consistent with public health, aesthetic, and engineering considerations, and without the deliberate or mischievous burning normal to the operation of the other two methods.

The first step above, the most primitive procedure, is known as "dumping." This step was taken long ago by almost every American community, but, unfortunately, it is about the only step ever taken by many of them. Many communities are, therefore, now faced with critical problems of refuse disposal, the solution to which may require drastic and unpopular increases in budgets.

The more advanced procedures are known as "land fills." The best of these may properly be described by the term "sanitary land fill," although the name has often been misapplied to some quite rudimentary disposal operations. Tremendous strides on the use and development of the sanitary land fill have been made over the past eleven years. Prior to 1941, there were only 3 cities in the United States using this method of refuse disposal. Today there are probably 400 cities, towns, and communities satisfactorily using the method. Expanding populations, however; have brought many of these face to face with problems of refuse disposal as urgent as those which confront their less progressive neighbors.

Open Dumps and Refuse Fills

The site

For any type of refuse disposal operation whatsoever, the only site acceptable to the public seems to be "somewhere else." Hardest of all is the finding of a site for an open dump or simple refuse fill.

The way in which refuse disposal problems may build up public antagonisms is graphically described by Frank M. Stead. 'In California many of our incorporated cities are surrounded by fringe areas which

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Note: Please forward all comments on this report to Chairman Henry W. Taylor, 151 W. Merrick Road, Freeport, N. Y.

are in reality unincorporated cities without any machinery for planning or carrying out the basic services of waste disposal. When roadside dumping becomes intolerable the governing body of the county usually provides "dump sites" and private scavengers collect refuse in the more profitable sections, the remainder being left to look after themselves. Invariably the city within such a fringe area looks outside its own boundaries for a refuse disposal site and locates it in the fringe area or in open territory which within a year or two becomes part of the fringe area. The natural resentment of residents of the fringe area against being a "dumping ground" for the city then effectively blocks the working out of a satisfactory solution to the refuse disposal problems of the entire metropolitan district."

Sometimes the city is unable to carry its refuse problems beyond its own limits. An example is St. Louis, which, being a commonwealth, is not in any county. It is, however, entirely surrounded by St. Louis County except on the east, where the boundary is the Mississippi River. The area in the county adjacent to the city and surrounding it consist of some 85 smaller municipalities. Neither within this area nor anywhere else in the county will county officials permit the disposal of any of the refuse coming from St. Louis. Since the cost of hauling it to the low river bottoms on the Illinois side of the Mississippi is prohibitive the City has no alternative but to conserve its present disposal fill sites by whatever means, sanitary or otherwise, until incinerators construction can be completed.

Generally speaking, the area least objectionable to the public as a site for a dump or simple refuse fill is one which is definitely substandard because of its unusability for one reason or another. Low-lying ground which can benefit by a fill is probably the most desirable site. However, gullies, abandoned ditches, ravines, and even canyons are very frequently chosen as the site for the city dump.

The key to the solution of the problem of refuse disposal sites, Stead believes lies in city and county governments accepting the responsibility for demonstrating that refuse disposal can be designed and carried out without damaging or blighting the disposal area. An excellent example of the soundness of this conclusion is Fresno, California, where insurmountable opposition to locating a sanitary landfill close to the city limits vanished after operation at a site four miles further away showed citizens what the method could accomplish. Another example is the Spring Creek Park Land Fill in New York City. Not a single one of the anticipated complaints has been registered during several years of operating and several newspapers have commented very favorably on the project.

Baltimore reports very good neighbor relations with a Housing Project located adjacent to the present landfill. The fill is operated in such a manner that the area nearest to the homes is used only during the winter months, while the area farther away is utilized during the summer season.

Materials Dumped

All manner of rejected materials find their way into the city dump. Most ordinances prohibit the placing of garbage in open dumps, but

there are few records of any attempts at enforcement in small communities, and in large communities—Los Angeles, for example—the difficulties of inspection make rigid enforcement next to impossible. Undoubtedly the greater percentage of open dumps still receive considerable amounts of garbage along with the other waste materials that are deposited. The number of operators of public dumps in California who take advantage of permission commonly granted to run hogs on such a dump is evidence of the presence in the refuse of appreciable amounts of organic matter.

Open dumps in which mixed municipal refuse is deposited are not permitted in most large cities or in the environs of large metropolitan centers. Many of the extensive refuse dumps of southern California have been closed in the past four years and the life expectancy of those remaining can not be great. New York does not permit open dumps within the City and even the method of cut-and-cover fills has lost favor due to the odor nuisance arising from its operation. The City of Baltimore permits no dumping of garbage or rubbish materials on open dumps. All materials are either disposed of by landfill or by incineration. Clean ashes and street dirt are allowed on open dumps for fill purpose only, usually on private property. These materials are screened very thoroughly to insure that no garbage or rubbish materials are present.

In all cities there is some irreducible amount of non-combustible material which must be disposed of by dumps or fills. Ashes from furnaces or incinerators, street sweepings, waste earth, and broken masonry and ceramic ware represent the almost totally unsalvable fraction of refuse. In many communities tin cans and broken glass are equally valueless and must be dumped.

The quantities of ashes and dirt disposed of in Baltimore in 1952 are shown in Table 1.

Table 1

Material	Cubic Yards Placed in Dumps	Tons Placed in Sanitary Landfill
Ashes	101,205.80 cu.yds.	13,895.75 tons
Street dirt	-	10,001.71 tons
Dirt	111,488.60 cu. yds.	-
Total	212,694.40 cu. yds	23,897.46 tons

In addition to ashes and dirt, 181,896.10 tons of mixed refuse and market refuse were handled. Had this material been reduced to 10% of its

weight by incineration, approximately 18,190 tons of ashes would have resulted. The total irreducible minimum of fill volume required by the City of Baltimore in 1952, therefore, was about 286,000 cubic yards. The 1950 census showed a population of 949,708 for Baltimore.

The fill requirements for Washington, D.C. are likewise impressive. Table 2 shows the overall production of ashes and miscellaneous non-combustibles in that city as of January 1, 1950.

Table 2

Source of Material	Annual Production in cu. yds.	Annual Fill Requirement cu. yds.
Household ashes (including D. C. and Pub. Bldgs.)	150,000 cu. yds.	112,000*
Private Haulers	300,000 " "	300,000
U. S. Government	50,000 " "	50,000
D. C. Agencies (including catch basin cleanings and grit from sewage treat. plant)	40,000 " "	40,000
Street and alley sweepings	300,000 " "	156,000**
Incinerator residue (10% of 2,600,000 cu. yds.)	--	260,000
or (5% of 2,600,000 cu. yds. if metal salvaged)	--	(130,000)
	Total	972,000 cu. yds.

* Assumes 25% of household ashes and cinders utilized by Highway Dept. and private contractors.

** Assumes incineration of 60% of all street sweepings and 20% residue, although it is more difficult to reduce than household or commercial rubbish.

From Table 2 it is evident that, at the 1950 rate of production, all types of non-combustible refuse for which disposal by dumping is the only possible method of disposal total 972,000 cubic yards annually. The Washington, D.C. 1950 population was 802,178. These data do not include

material from building excavations or dredging operations for which spoil areas must be found.

Burning of Open Dumps and Land Fills

The operation of dumps and the more elementary types of land fills customarily involves burning. In fact, many county and town ordinances in California and elsewhere require daily burning of dumped combustible materials. The expectation is that most of the waste that is contaminated will be destroyed or somewhat purified by the heat of the fire, and that food materials will be so reduced as to minimize rat infestation of the dump. Reduction in volume of refuse is another reason for burning at many dumps, especially where available fill capacity is limited and new sites are either unavailable, located at great distance from the city, or extremely costly. A few communities justify burning on the basis of the resulting isolation of salable metals.

The refuse disposal operation at Bakersfield, California is a typical example of a normal procedure involving daily burning of combustible refuse to conserve fill area, except that garbage as well as rubbish is dumped and hogs are permitted on the site. Rubbish brought in by municipal and private vehicles is dumped in one area of the disposal site, while garbage brought in by municipal trucks is dumped in another area. The first loads of the day are deposited close to the edge of the fill and each successive load is dumped farther away so that salvagers can have easy access to the material. During the night only, hogs are allowed to run over the refuse and on the following day the remaining material is pushed over the edge of the fill and ignited. Occasional loads of dirt and rubble are used to cover and level the newly formed portions of the fill so that trucks and other vehicles may approach the advancing edge of the dump.

The necessity for burning to conserve present disposal sites in St. Louis and in Washington, D.C. exemplifies the problem confronting many of our large cities, although in each of these cases it is considered an expedient which can be tolerated only until new incinerators are completed.

In 1946 the citizens of St. Louis passed a 4 million dollar bond issue to establish a rubbish collection and disposal service. A committee appointed to study all aspects of the problem made a careful survey of acreages that could be used for landfill disposal and found that all available fill capacity would be exhausted in about 4 to 7 years. On the advise of a competent consulting engineer it was decided to use the landfill method only until incinerators could be constructed. Land fill disposal was begun in 1949 with full realization that methods of operation could not involve a strictly sanitary landfill because of the need for conserving available disposal sites. Rubbish collected in the south half of the city is being disposed of in a fill in a reach of the Mississippi River. A fill of non-combustible material is constructed in the river along the inner harbor line. The space between this fill and the river bluffs is then filled with combustible material and compacted with a 10-ton dozer. Deliberate burning is not practiced but fires break out and only a superficial effort is made to extinguish them unless the wind direction is such that the smoke is carried westward into a residential area adjacent to

the river. If it were not for this burning the dump area would have been exhausted a year ago. As it is, the area will be filled before the end of 1953. South side rubbish will then have to be hauled to the north side fill for about a year until the incinerator which is to handle this material is completed. Such a prospect involves an increase in haul of some 6 miles and will add about 100,000 dollars to the annual cost of collection. The space remaining in the north side dump, described later in this report, is sufficient for about 4 years accumulation of rubbish, after burning, collected in that section of the city. The added burden on this land fill of a year's contribution from the south side will undoubtedly so deplete its capacity that by the time two 400-ton incinerators are in operation the city will be faced with a serious problem of disposal of incinerator ash.

The situation in Washington, D.C. reported in 1950 and 1952 also reflects the general problem of heavily populated cities in the matter of burning to minimize land fill requirements. Incinerator capacity is sufficient to care for but 40 percent of the household, commercial, and U.S. Government combustible refuse of the city. The remaining 60 percent (approximately 1,600,000 cubic yards per year) is being handled by "controlled open-burning" at Kenilworth. During the winter of 1949-50 as many as 1100 truck loads of rubbish were deposited on the Kenilworth Fill on peak days. On windy days a bonfire of the resulting proportions constitutes an extreme fire hazard to recent large scale housing developments east and south of the site, as well as a potential nuisance to residents. Such burning could not be transferred to any other point within the confines of the District of Columbia, nor is there any other location within reasonable truck haul in Maryland or Virginia where such practice would be permitted by the authorities or tolerated by the residents of the metropolitan area.

Until such time as incinerator capacity may be constructed there is no alternative but to continue open-burning at Kenilworth and to maintain its disappearing fill capacity by hauling the residue elsewhere. To haul this material to landfills in other sections of the city involves long distances over public highways, which would entail inordinate costs. In addition it would give an air of permanence to the operation in the minds of citizens who are looking forward to the cessation of dumping and burning operations by the time the Kenilworth Fill area is brought up to established grade. The most practical solution seems to be the utilizing of a nearby Bird Sanctuary for a fill with residual materials hauled from the burning operation at Kenilworth. Some 80 to 100 truck loads of residue must be hauled each day. The estimated fill volume at the Bird Sanctuary is 660,000 cubic yards. With an average depth of fill of 8 feet the site will provide space for from 4 to 7 years production of residue at Kenilworth, depending on the extent to which metal is salvaged and how long citizens continue to tolerate the inadequate methods of refuse disposal currently practiced in their communities.

Los Angeles is an example of a city in which great distances to possible new sites of refuse fills might be an important factor in the burning of refuse on the extensive dumps located within the metropolitan area. Problems of air pollution have, however, ruled out burning as a

measure for conserving existing fill areas and have been responsible for a program which has all but ended the once widespread practice of burning on dumps.

Seacoast and river cities that have access to swampy or marshy land which might well be reclaimed by refuse fills often practice burning to conserve existing fill areas because of the cost of dikes necessary to dewater the site and to prevent tides or floods from cutting away the finished fill and depositing refuse along the short line. In the operation of the sanitary land fill at Berkeley, California, burning is practiced for this reason. Private rubbish collectors deliver about 100 tons of material each day. This is dumped near the edge of the existing fill to facilitate salvage. Each evening it is burned over and the residue is later pushed into the fill where it is compacted and covered with concrete rubble and waste earth brought in by local excavating contractors. One hundred ten tons of city refuse containing garbage, brought in daily by municipal trucks, is placed in another part of the fill without burning.

At the present time the city of Berkeley is constructing a bulkhead dike at a cost of approximately 125,000 dollars to make available 50 acres of new fill area. At an average depth of fill of 10 feet refuse plus 2 feet of cover this area will be used up at the rate of 5 acres annually. If the practice of burning refuse is abandoned the fill area required per year will be approximately doubled. Although the cost of diking is paid by setting aside ten percent of the gross receipts from the direct charges to citizens for refuse collection service, 125,000 dollars represents a considerable sum to a city of 115,000 population and must be reflected in the rates charged for service.

Several of Berkeley's smaller neighbors practice burning of their dumps, but do not operate sanitary land fills such as has enabled Berkeley to reclaim 120 acres of tidal mud flats. The worst practice is exemplified by a few northern California communities in which it is the practice to dump refuse on the ground, allow hogs to root in it overnight, burn it to facilitate salvage, then finally push the remains over the edge of the fill with a dozer.

General Operation of Dumps

Usually a caretaker is assigned to the dump to direct the trucks and other vehicles to proper locations for dumping their refuse at or over the edge of the fill instead of on the finished surface where they must be moved by the operators of the dump if the elevation desired for the surface of the fill is to be maintained. If the dump is privately operated, the caretaker also collects a fee from individuals bringing refuse to be abandoned.

Cost of operating open dumps varies greatly. During times of high salvage prices, it is often possible to secure contracts or leases under which the contractor not only provides the site but also provides the necessary operations of the dump in order to have the refuse delivered and to obtain the salvage therefrom. These are exceptional cases, however, and in average times it is necessary to buy or lease the site, pay a caretaker, and provide equipment occasionally to keep the surface of the dump reasonably smooth and make any necessary cover of earth.

If the dump is maintained and operated by a city which collects all

refuse from its citizens without charge, the hours that the dump is open can be definitely limited. On the other hand, where refuse collection service is very limited and householders generally bring their own rubbish to the dump, the dump may have to be kept open from early morning until dusk seven days a week.

Public Health Aspect of Dumping

The nature of an uncontrolled open dump as an ideal dwelling place for rats is well known. The rat population in any open dump is directly proportional to the food supply which finds its way into such fills in the form of garbage, fragments adhering to tin cans, and so forth. As pointed out by Mr. Stead, the real public health concern arises from the fact that a refuse dump is an excellent meeting place for field and domestic rodents. Field rodents such as ground squirrels are considered to be the principal reservoir of bubonic plague infection in California. The same vector flea infests both squirrels and rats. Therefore it is important that there be no opportunity for the transfer of infected fleas from one species to the other as this could result in exposure of the urban population.

The suitability of the open dump for the breeding of flies and mosquitoes is likewise well known. An epidemic of Encephalitis spread in California's central valley in 1952 by Culex tarsalis underscored the importance of mosquito control at every possible breeding place.

The nuisances from odors of burning garbage, oil, and other combustibles, and from the smoke resulting from burning refuse are well known. Less well known is the air polluting character of quite small amounts of gases and particulate matter resulting from burning, and the fact that many cities in the United States are at or near the threshhold of smog at certain seasons of the year. As the population of the United States grows and the size and industry of its cities increase, air pollution will become a matter of increasing public health concern.

Still another consideration which may gain in importance as population concentrations increase is the danger of ground water contamination by leachings from dumps. Preliminary results of current research sponsored by the State Water Pollution Control Board of California indicate that the danger of ground water contamination from many dumps and refuse fills may be much greater than had been previously assumed. It may well be that as cities grow the protection of the public health will make necessary increasingly stringent regulations concerning the maintenance and operation of dumps and landfills of all types.

Costs of Disposal by Dumping

In cases where municipal dumps are kept open 7 days a week, costs have run as high as 47 cents per cubic yard. On the other hand the south side fill in St. Louis, where dump laborers are paid $246.50 per month, costs but 13 cents per cubic yard; and the cost of dumping ashes and dirt in Baltimore averages 15.6 cents per cubic yard. While the cost of dumping varies considerably from city to city depending on the local situation and pay scales for labor, it is the cheapest method of refuse disposal when measured solely in terms of actual cash outlay required in the operation.

The Use and Future of Open Dumps

The only advantage that can be claimed for the open dump is its economy. For this reason alone it has many advocates, especially in smaller cities, where it continues to be the predominant method of refuse disposal. In 1949 a comprehensive questionnaire was prepared and mailed to 599 cities with populations ranging from 5,000 to over 500,000 as a preliminary to the preparation of the "Report of the APWA Committee on Refuse Collection and Disposal" which was later issued by that Association under the title "Refuse Collection and Disposal Practices." Information compiled from the 200 answers received are shown in Table 3. The fact that more than half of the cities in the 5,000 to 10,000 group used the open fill is not reassuring.

Table 3

Population	Cities Answering	Method of Disposal				
		Open Fill	Sanitary Fill	Incinerator	Hog Feeding	Reduction
500,000 and over	12	1	8	8	5	-
100,000 to 500,000	30	2	17	14	11	3
50,000 to 100,00	21	4	9	7	7	1
25,000 to 50,000	23	5	9	7	11	-
10,000 to 25,000	41	9	15	12	12	-
5,000 to 10,000	73	38	14	7	17	-
Totals	200	59	72	55	63	4

The use of open dumps for the disposal of refuse will undoubtedly continue indefinitely for those small communities where (1) sites are available in locations that make the use of them unobjectionable to the people of the community and (2) where the volume of refuse is so small that it is not economically sound to afford the cost of equipment which can promptly and regularly cover the refuse in a sanitary manner. Where these practices must continue, it is hoped that they will be regulated by enforceable ordinances of the health authorities which will positively prohibit the inclusion of garbage in the refuse and will require occasional complete covering with adjacent earth or soil. There is a growing opinion that open dumps should be permitted only under strict and careful regulation.

Sanitary Land Fills

General Considerations

Of the 200 cities answering the questionnaire summarized in Table 3, 72 were utilizing the sanitary landfill method of refuse disposal. This

is a greater number than was using any other method—a significant fact when it is remembered that a large number of smaller cities use the open fill, that many of the larger cities lack the land area needed for the method, and that twelve years ago the method was all but unknown. At the time the survey was made, three more cities were preparing to use the sanitary land fill, while only two cities indicated that their operations were other than satisfactory.

Sanitary land fills are of two principal types—the area-fill and the trench-fill, sometimes called "fill and cover" and "cut and cover." The nature of the land available generally governs the choice of type, although the availability of cover material may be a factor. Area-fill involves the fill in of low lying land, abandoned quarries, canyons, hillsides, etc., with a series of cells consisting of refuse surrounded by earth.

The trench-fill is probably the simplest and least expensive method of operating a sanitary land fill. Ordinarily a trench 2, 3, or 4 feet in depth is cut in relatively level land in order to obtain material with which to cover the refuse later deposited in the trench.

A main essential to these operations is the adoption of methods that will assure sanitary conditions. Of primary importance is that the fill be completely covered at the end of each working day. A further requirement is that the top covering be approximately two feet or more in depth in order to assure complete control of rodents and flies. It is not necessarily that a covering of this depth be made each night, but it is important that such a covering be provided before operations are moved to an adjoining area. Such a covering assists in the control of odors, prevents the escape of obnoxious gases, and is helpful in the prevention of fires within the fill.

It is probable that there are fewer difficulties to overcome if the soil available for cover is a sandy loam. Working in gumbo is the most difficult because the surface of the fill is subject to considerable cracking. An occasional dragging of the surface tends to fill the cracks and has proved very successful. The spreading of ashes over a clayey or gumbo soil has generally proven beneficial.

Of particular significance in the progressive development of the sanitary land fill is the ingenuity displayed in (1) selecting sites, (2) adapting methods to meet the particular sites that are available, (3) utilization of equipment, and (4) variations of methods in meeting problems created by the weather such as extreme cold or heavy rains. Ten years ago, it was doubted that the sanitary land fill could be successfully used in the cold northern states throughout the winter. Methods have been adopted that are producing very satisfactory results in handling refuse disposal in the north throughout the entire winter season. Notable have been such accomplishments in North Dakota, Minnesota, Wisconsin, upper Michigan, and upper New York State. In the southern states, it has been necessary to devise methods which will permit the disposal of refuse despite heavy rainfall. The city of Fort Worth and many other cities have developed satisfactory methods.

Land Fill Operations

The City of New York has created thousands of acres of useful land

by filling in low lying areas and marsh lands with refuse. Four sites are in use at the present time and the City's new policy is to fill only property owned by the City.

In general the method of operation is to prepare the site by filling with sand or dirt or other innocuous material to a level above tidal action and to enclose the area with a dike to prevent leaching out obnoxious material. The cover, consisting either of sand or dirt, is then stockpiled. The operations are conducted in rather narrow strips in the following manner: material is dumped along the edge from the trucks and then is bulldozed down the bank. Scrapers bring material for covering the open face and at the end of each day's operation the refuse is completely enclosed. The sand cover is approximately two feet thick and both the cover and refuse are fairly well compacted by the travel of the heavy equipment across the surface. In addition, a tank truck equipped with spraying device continually sprays the open face with deodorants.

The north side fill in St. Louis is another example of a sanitary fill used successfully by a large city although, as mentioned in a previous section of this report, it is too limited in extent to serve as other than a temporary device. Rubbish collected in the north half of the city is disposed of on 85 acres of low land leased from the Chicago, Burlington, and Quincy Railroad. The land is low in elevation and subject to overflow at high stages of the Mississippi River. Some 37 acres have been filled to an average depth of 17 feet in four years of operation. Although the site is typical of an area fill operation it is necessary to excavate a trench of sufficient depth to get necessary cover material. A 2-1/2 cubic yard drag-line is used to dig the trench and stockpile cover dirt on top of the completed fill. After dumped material is burned about a foot of dirt is pushed over it by means of a bulldozer. This amount of cover has been found satisfactory inasmuch as there is no garbage or other readily putrescible matter in the refuse. The fill is brought up in two lifts of about 8 feet each. No specific effort at compaction is made but some results from the dozer running over each lift as the fill is constructed, and from two 15 cubic yard, trucks running over the fill and backing up to dump.

The City of Baltimore reports experience with both sanitary trench-fills and area-fills. The area-fill disposal sites are principally operated by individual property owners who charge a fee of 25 cents per cubic yard for dumping refuse. Mixed refuse is dumped, and spread in a layer about 6 feet thick by a bulldozer. When cover material becomes available it is placed on top of the refuse to a depth of 9 to 12 inches. The cover material is furnished by the property owner who obtains it from construction contractors, charging them a fee for the privilege of dumping. Successive 6-foot layers of refuse are added until the fill surface has reached the desired final grade. The weight of delivery equipment provide the only compaction that is obtained in the process.

The Sanitary Landfill in Baltimore is operated as a trench-fill. Refuse material is dumped by the collection vehicles at a distance of from 10 to 15 feet from the edge of the dumping face. A 22-ton bulldozer pushes the waste over the edge of the dumping face and in this process the operator raises the blade, thereby permitting the full weight of the

equipment to be applied at the edge of the fill. This is a continuous process throughout the eight hour working day. The materials coming to the disposal site are proportioned so that a combination of 50 percent garbage and ashes, and 50 percent rubbish and street dirt goes into the fill. A 40-ton crane equipped with a 1-1/2 cubic yard drag line bucket operates along the top of the fill at the edge of the cell that was completed on the previous day. It operates continuously during the working day digging cover material from the surface of the area to be filled on the following day and stockpiling it until needed.

When the filling has proceeded to any desired point a 6-inch prime cover is spread to prevent the blowing about of debris as well as to cover the unsightliness of the placed refuse. Wherever it is found necessary, particularly in hot dry periods, a strong disinfectant, having a creosote base and a disinfecting co-efficient of 6, according to the method of the Food and Drug Administration, is liberally sprayed over the waste and on the site of operations generally. The dust is laid by frequent spraying of water by 1,000-gallon tank flusher. On occasion, calcium chloride and waste all have been used in connection with the water. At the close of the day's filling, a final 2-foot cover is placed by the bulldozer over the top of the compacted fill. The crane then moves onto the cell and helps spread the cover, in addition to shaping the front slope by crushing bulky boxes and barrels and further compacting the fill under its weight. A light coat of cover material is applied to the slope by the crane. Thus at the conclusion of each day's operation both the top and the slope are completely covered.

At Winnetka, Illinois an operating procedure for a trench-fill has been worked out which has a number of advantages. The fill from the bottom of the trench to a final elevation some 5 feet above the original ground surface is made in two lifts. The first lift brings the refuse fill up to the original ground surface where it is covered with about 6 inches of earth, cinders, or other dry material stockpiled for the purpose. The first lift is started from a permanent access road which forms one end of all the trenches, and as work progresses, the trucks are backed in over the new fill with its light cover to reach the dumping point. The second lift is started from the far end and progresses back to the access road, being covered by dirt excavated from the next trench.

The temporary cover over the first lift is sufficient to prevent odors during the two-week period that it is in use, and the continued traffic over it compacts it so that no rat trouble has developed. The only disadvantage, which might limit the method on large operations, is that only one truck can be dumping at a time since two cannot pass on the narrow filled trench if the adjacent soil is muddy.

San Francisco has been using a sanitary area-fill ever since the legal closing of an incinerator a number of years ago. The fill is operated by two private companies which cooperate in the work. Refuse is brought out in gondola cars, dumped on mud flats, and covered on the top and face with soil and rock quarried nearby by use of explosives and normal quarry equipment. Little effort is made to compact the fill. Plastic flow of the underlying mud takes place but the degree is unknown. There are no rats about the operation although a few flies are in evidence. A

tremendous number of sea gulls frequent the site. Opening of a section of the fill which had been in place for 12 years revealed that little decomposition of fruit and vegetables had taken place. Colors of vegetable material were intact until exposed to the air for a few minutes. Newspapers could be read and tin cans were bright, although some electrolysis had taken place. A temperature rise of from 6 to 8 degrees was observed in an 8-foot depth.

Many small and medium sized cities in California employ sanitary land fills. In 1950-1951 a study* was made of 13 cities ranging in size from 5,500 to 244,000 population. Data from this study are presented later. Of particular interest is the city of Fresno which was one of the first cities in the United States to operate a land fill on flat ground by the trench-fill method. In this operation a crane is located at the toe of the fill slope where it is used to pull the load from diaphram type refuse trucks, to dig the trench for the next cell, and to cover the newly placed fill. It is also used for compacting the fill by dropping a 1-1/2 cubic yard bucket, loaded with earth being dug from the trench, upon the refuse from a height of about 10 feet. Other compaction is obtained by the refuse vehicles passing over the fill. This location of the crane is considered unorthodox by many who prefer to work from the top of the fill. Inasmuch as the Fresno fill increases some 30 feet from the bottom of a 12-foot trench to the top of a 3 to 4-foot cover, the crane is probably working to its best advantage from the mid-elevation at the intersection of the new fill and the original ground which is to be dug away to form a new trench.

Disposal of Garbage in a Sanitary Land Fill

A large percentage of the cities and communities using the method have found that they encounter no problem when garbage is included in the refuse being deposited in a sanitary land fill when regular, careful, and complete covering is provided. Where burning of combustible components of rubbish is a part of the method of operation, it is important that garbage be dumped in a section of the fill which is not to be ignited. The fact that garbage may be used in the sanitary landfill is increasing in importance, especially to those many communities where raw garbage is now being fed to hogs and where laws are being passed to stop such feeding because of vesicular exanthema. The thirteen cities surveyed in California all incorporate garbage into their sanitary land fills. Winnetka, Illinois does likewise. Of the larger cities discussed in this report, New York, Baltimore, and San Francisco place garbage in sanitary land fills. In Washington, D.C., garbage is fed to hogs, and St. Louis is grinding its garbage into the river.

Refuse containing household garbage in ordinary amounts will average about 100 pounds per cubic yard heavier than refuse which does not include garbage. The added truck capacity, therefore, would be practically all that would be required for those cities now operating land fills and which must pick up the burden of garbage disposal in the near future.

*"An Analysis of Refuse Collection and Sanitary Landfill Disposal," Bulletin 8, Sanitary Engineering Research Laboratory, University of California.

In cities where land area for fills is extremely scarce, exclusion of garbage only serves to delay a little longer the day when their land fill activities will have to be confined to the disposal of non-salvable non-combustible material.

Depth of Land Fills

The depth to which refuse may be placed in a land fill depends upon a number of factors—the depth of the depression to be filled; the permissible change in topography, especially in flat areas where the trench-fill must be used; the difficulty of preventing surface cracks and subsequent invasion of the fill by rats, or the release of odors; the use to which the filled land is to be put; the method of fill construction; and similar considerations. For fills to be put to useful purpose in a reasonable number of years a maximum depth of about 8 feet has been advocated. In practice, however, much deeper fills are generally constructed. Table 4 lists some fill depths recently reported, principally in California.

Table 4

City	Depth of Trench	Total Depth of Refuse in Fill	Depth of Cover
Baltimore, Md.	-	15 feet	2 feet
Bakersfield, Calif.	-	25 "	-
Berkeley, "	-	10 "	1-1/2 "
Fresno, "	12 feet	27 "	4 "
Lodi, "	7 "	12 "	2 "
Long Beach, "	-	24 "	-
Palo Alto, "	8 "	24 "	2 "
Riverside, "	6 "	14 "	2 "
Sacramento, "	-	25 "	2 "
Stockton, "	12 "	18 "	2 "
Watsonville, "	9 "	16 "	3 "
Winnetka, Ill.	6 " (Est.)	11 "	2 "
Washington, D.C. (Bird Sanctuary)		8 "	-

Cover on Land Fills

The minimum depth of earth cover of 2 feet usually recommended for satisfactory operation of land fills is based on the maximum distance

a rat will burrow (12 inches) plus an allowance for uneven settlement of the fill. In individual cases the depth of cover used depends on proposed use of the finished fill, the degree of compaction, the availability and cost of fill material, and similar considerations. On well compacted fills 12 inches of cover has often proved satisfactory, while those to be put to some useful purpose in the near future may require 3 or 4 feet of cover. In general, the depth of cover used on sanitary land fills varies from a few inches to 2 feet or more. The thinner cover seems characteristic of area-fills while the thicker cover is most often found on trench-fills where providing adequate cover has little effect on the economy of the disposal operation. The depth of cover used in a number of land fills is in the right hand column of Table 4.

Compaction of Land Fills

It is extremely important that a high degree of compaction be secured in any sanitary land fill. The need for compaction if the filled land is to be used as an area on which to construct buildings has long been evident. Only recently, however, has its importance in connection with engineering economics been seriously considered.

Compaction ratios, defined as the ratio of volume of refuse delivered to the site to its volume in the completed fill, for a number of cities is shown in Table 5 along with other pertinent data.

Table 5

City	Compaction ratio	Land Requirement	
		Acre-ft. per year per 1,000 services	Acre-ft. per year per 10,000 pop.
Berkeley, Calif.	2.0	2.4	7.7
Fresno, "	2.5	2.1	6.6
Lodi, "	3.7	4.0	13.7
Riverside, "	-	3.5	11.4
Sacramento, "	-	1.8	5.7
Stockton, "	2.3	3.7	10.7
Winnetka, Ill.	4.9	-	-

Inasmuch as the methods used for compaction in California cities are those commonly used elsewhere, it is reasonable to assume that 2.5 to 3 represents the usual compaction ratio. Various reports have assumed the compaction ratio be 3.3 for a good degree of compaction. Winnetka, Illinois has, however, demonstrated for several years that with care it is possible to achieve a compaction to nearly 20 percent of original volume instead of the usual 30 to 40 percent. What this additional degree of compaction could mean to a city might be illustrated by a hypothetical example.

Suppose that a certain fill area is sufficient to take care of 50 truck loads of refuse per day over a period of 5 years utilizing good compaction to reduce the fill volume to 30 percent of the original volume. Suppose further that the next fill area available is 8 miles further, and that with good care it is possible to obtain a compaction to 20 percent of the original volume. The saving resulting for the greater care in compacting would amount to 600,000 truck miles.

As cities continue to grow, the matter of availability of sites and the fewest possible ton miles of hauling to disposal points becomes more and more important in dollars and cents. At Santa Monica, California, for example, an old quarry site was available in the middle of the city. The City Manager and City Engineer recognized the importance of obtaining the greatest possible degree of compaction because of the savings that result from the very short haul. They recommended the purchase of equipment considerably heavier than might have been utilized. As a consequence, the City was able to use the site for almost a year longer than under ordinary conditions, with resultant savings of many thousands of dollars.

A disadvantage of sanitary land fills often cited is that fill volume is wasted because all the refuse goes into the fill instead of only the residue of combustion. Seldom, however, will this residue amount to less than 10 percent of the volume delivered to the incinerator. Frequently it will run 13 to 14 percent. The residue representing the 10 percent figure is probably not susceptible to compaction. If sufficient care is given to the sanitary land fill to secure compaction to 20 percent, only twice as much volume would be required as for the residue after incineration. The economic implications of compaction of landfills are worthy of careful study.

Land Requirements

As has been noted, the land requirements for sanitary fills is closely related to the degree of compaction achieved. Its extreme importance lies in the degree to which available area is the factor that limits the application of the sanitary landfill method of refuse disposal. The typical judgment of municipal officials in many cities is that the sanitary landfill method of disposal is good and very economical; however, the scarcity of fill areas makes it almost mandatory that a more permanent method of disposal be developed.

Land requirements for several California cities are included in Table 5 which shows that the land requirement for seven cities averaged 10.6 acre-feet per year per 10,000 population, at an average compaction ratio of 2.6.

Use of Land Fills

One of the principal virtues of the sanitary land fill method of refuse disposal is the reclamation of useful land area from former swamps, marshes, tidelands, etc. The City of New York has created thousands of acres of parks, building, and residential sites, and four areas presently being filled will become huge parks with golf courses, tennis courts, baseball diamonds, and other recreational facilities. In Baltimore the area being filled will be developed as a recreational site to be maintained

by the Bureau of Parks. Similar building and park areas are being created in the District of Columbia, in Los Angeles, and in numerous other American cities. Some land fills in St. Louis are being used for truck terminals and a bulk oil distributing plant. In Berkeley, California, the Golden Gate Fields race track and adjacent automobile parking area occupy a part of the 120 acres already reclaimed by the refuse fill and once intended for an airport. San Francisco has reclaimed 140 acres and light industry is operating on 36 acres of the original fill. Fresno, California has grown crops on the top of its fill; and Winnetka is utilizing part of the completed fill as an auxiliary municipal service yard.

In general, almost every sanitary land fill is expected to yield new land area for some useful purpose. Settlement of fills, therefore, becomes an important factor. In it is involved, as previously noted, the whole matter of depth of fill, methods of construction, and degree of compaction. In San Francisco elevation observations have been made since 1944 although some records are meager because of the disturbing of bench marks by settling. The records do show, however, that the rate of subsidence decreases after 3 or 4 years. A fill placed in 1940 settled 3 to 5 inches per year during the four year period from 1949 to 1953. Light industrial buildings recently constructed on the fill are built on telescoping concrete columns in order to compensate for settlement and maintain the building floor at its design elevation.

The highly compacted fill at Winnetka, Illinois has settled rather evenly with only a 4-inch subsidence being noted in the sections that have been completed one year or more.

The loads which may be superimposed on a refuse fill limit its use as far as buildings are concerned unless, of course, it is desired to carry foundations completely through the fill and onto solid strata. Generally mat foundations are used which spread the building load over the entire building area. Extreme caution must also be exercised if the fill is to be opened for the construction of utility lines. Difficult problems may result from odorous conditions, excessive corrosion of pipes or conduits, and rupture due to inequal settlement of the fill.

Equipment Use

In the study of California cities (see footnote, page 16) data were taken in order to define the probable limits for the amount and type of equipment required for satisfactory operation of the landfill method. The results are shown in Tables 6 and 7 for area-fill and trench-fill operations.

No data are available on the hours devoted to various operations in the Sanitary Landfill at Baltimore. The equipment, however, is in use throughout each 8-hour working day. It consists of: one 40-ton P & H crane, equipped with a 60-foot boom and a 1-1/2 cubic yard drag line bucket; one TD-24 International Tractor, equipped with caterpillar pan, having a total weight of 23.1 tons; and one TD-24 International Bulldozer, equipped with blade that has been raised approximately 3 feet to permit a greater "bite," and having a total weight of 22.1 tons.

Cost of Sanitary Land Fills

The operating costs per ton of refuse discharged into sanitary land

Table 6

City	Type of Equipment	Equipment-Use Hours per 1,000 Cu. Yds. Handled		
		Spreading and Compacting	Covering	Total
Bakersfield	1 Caterpillar D-6 with dozer blades	-	-	11.9
Berkeley	1 International T-9 with dozer blade	3.4	4.4	7.8
Burbank	1 Caterpillar D-7, 1 D-4 both with dozer-blade; 1 Sheepsfoot Roller	-	-	20.4
Sacramento	1 Caterpillar Mod. 50 with dozer blade; 1 Sheepsfoot Roller	5.8	1.0	6.8
Average				11.7

fills in seven California cities for which adequate information was obtained in 1950-1951 are shown in Table 8. It is notable that the cost to these cities averaged 81 cents per ton, and that this represented, on an average, 8 percent of the total cost of collecting, transporting, and disposing of refuse.

In comparison with these values the cost of fill in the North Side dump in St. Louis was but 18 cents per ton. Baltimore reports a unit cost of 49.2 cents per ton for its Sanitary Landfill; and about $1.75 per ton for constructing an area-fill on private property where the owner charges a fee of 25 cents per cubic yard for dumping. In San Francisco the cost is unusually great because of the expense of obtaining cover material which costs 54 cents per cubic yard to quarry.

It is of interest that the Winnetka operation involving special care in compaction cost but 79.5 cents per ton in 1948—and is, therefore, probably no more expensive than the average operation in California.

Salvaging on Fills

Salvaging on the site of sanitary land fills is a common, although by no means universal, practice which fluctuates with the market value of salvage materials. In the eleven California cities listed in Tables 6 and 7 salvaging in some form is carried out at all disposal sites except those at Burbank and Watsonville. The practice varies from that at Lodi, where one man regularly visits the city owned and operated site to pick up large objects of tin and iron, to that at Long Beach where extensive salvage activity is carried out at a privately owned rubbish dump. Rags, waste paper, metals, and glass are the principal objects of salvage.

Table 7

City	Type of Equipment	Equipment-Use Hours Per 1,000 Cu. Yds. Handled		
		Spreading and Compacting	Covering	Total
Fresno	1 Link-Belt Speeder with 1-1/2 cubic yard drag bucket and 70 ft. boom	4.5	1.0	5.5
Palo Alto	1 Link-Belt Speeder, L.S.-71, with 3/4 cubic yard clamshell bucket and 40 ft. boom	-	-	17.0
Watsonville	1 Link-Belt Speeder with 3/4 cubic yard drag bucket and 40 ft. boom	6.4	4.2	10.6
Stockton	1 Unit crane with 5/8 cubic yard drag bucket and 40 ft. boom		2.0	
	1 International TD-14 with dozer blade	3.9		5.9
Hardwicks' Disposal Pits (Long Beach)	1 Caterpillar 8-R with dozer blade; 1 LaPlant-Choat 15 cubic yard Carryall	-	-	2.6
Riverside	1 International TD-14 with dozer blade	4.6		
	1 International TD-18 with Bullclam attachment		3.4	8.0
Lodi	1 Allis-Chalmers HD-7 with Bullclam attachment	12.0	2.9[a]	14.8

[a] No trenching (Performed periodically by contract)

In Washington, D.C. magnetic separation of ferrous metals has been practiced primarily because of the desire to conserve fill space and to improve the character of the fill itself by removing tons of steel drums, cans, bed springs, etc. The market for such poor quality scrap in that area fluctuates greatly and is often such as to produce almost no revenue if, indeed, it can be sold at all.

Good practice requires that the salvagers carry out their operations in as neat a manner as possible; although it is recognized that the best of such operations always create a disagreeable and littered appearance at the dump site. The salvagers should also be required to remove the salvaged material as frequently as is at all practicable.

Table 8

City	Year	Disposal Cost - Percent of Total Cost	Disposal Costs Dollars per Ton
Berkeley	1950-1951	4.6	0.31
Fresno	1950-1951	3.9	0.33
Lodi	1950-1951	12.9	0.79*
Oroville	1950-1951	7.9	1.28
Palo Alto	1949-1950	14.9	1.57
Riverside	1950-1951	7.0	0.53
Stockton	1950	4.7	0.66*
Average		8.0	0.81

* Includes equipment depreciation or rental

CONCLUSION

The practices and problems of the communities cited are believed to be representative of those in other United States cities.

The growth in popularity of the sanitary landfill method of refuse disposal in recent years is evidence of advancing sanitary standards on the parts of citizens and their elected officials. New problems such as ground water pollution from fills, use of disposal sites by housing developments, and other matters related to a growing population, however, may well result in the method becoming inadequate at a rate faster than it is being adopted by cities to which it presently seems admirably suited.

In view of this, the extent to which modern cities adhere to primitive methods of disposal gives the more cause for concern, as it is indicative of the lack of progress toward sound planning for refuse disposal. The matter has been approached as though it were a whole series of unrelated problems. The responsibility for solving refuse disposal problems is a responsibility of government, for people can not work out the solutions as individuals. Ways in which municipal officials can be led to understand the value to a community of proper disposal of its wastes might well be given greater thought by future Task Committees.

Respectfully submitted,

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Subcommittee of the Sanitary Engineering Division on Dumping and Landfill

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a. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
b. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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